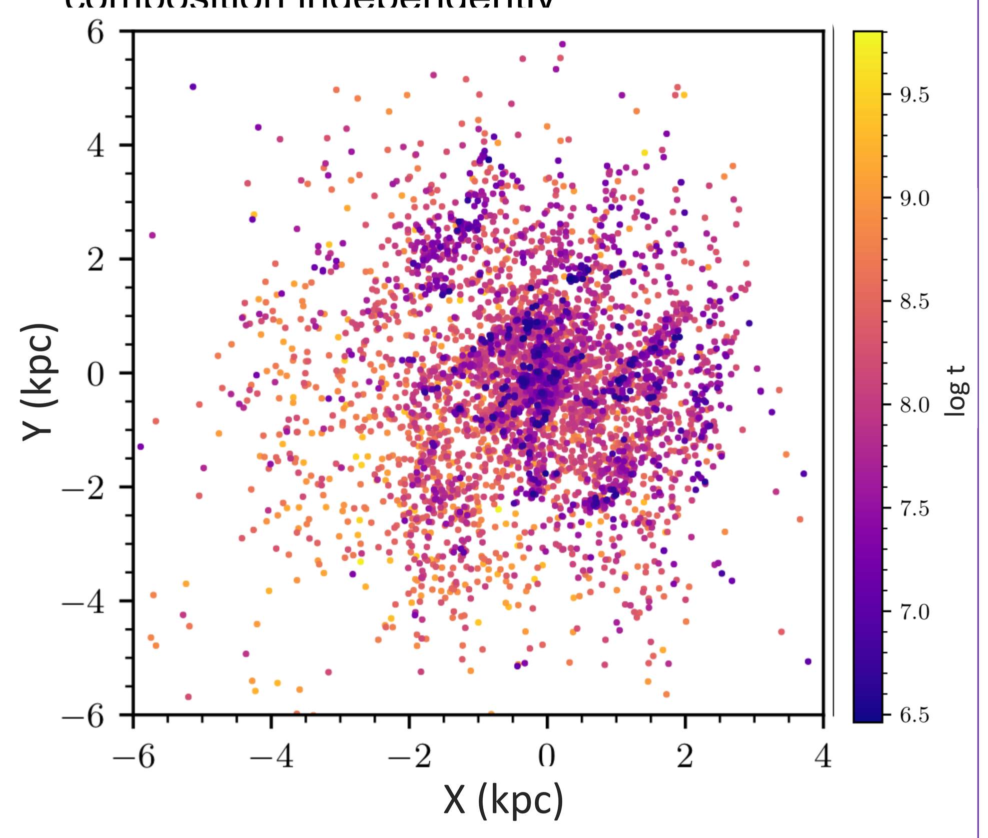
Only the Special Survive: Star Cluster Disruption in Galaxy Simulations

Alessa I. Wiggins[1] , Sarah Loebman[2], Jonah Otto[1], Peter M. Frinchaboy[1]
[1]Department of Physics and Astronomy, Texas Christian University, Fort Worth, TX 76109, USA
[2]Department of Physics and Astronomy University of California, Merced, Merced, USA

1. Introduction

- **Star clusters** are groups of stars (10^4) that are born together and are bound by gravity, many of which are found in the disk of the Milky Way galaxy
- The majority of stars in disk galaxies are born in star clusters (including our sun ☀)
- Studying these star clusters reveals essential information about the rich history of our Galaxy, as we can measure their age and their chemical composition independently



Top-down view showing the locations of star clusters that can be found in the disk of the Milky Way galaxy. Star clusters are often used as a tool to understand the history of our galaxy.
Credit: (Hunt et. al 2018)

2. Simulations

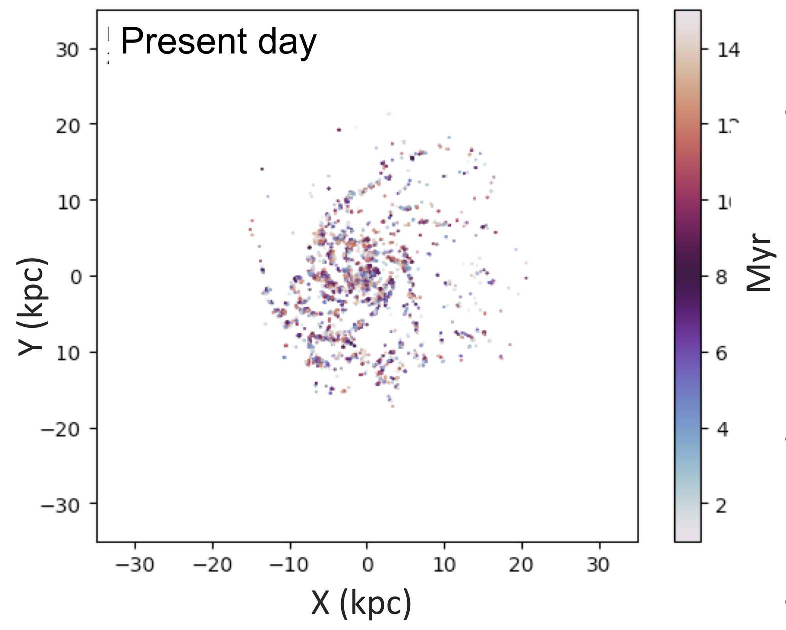
What star clusters am I studying, and why?

- While some clusters interact with their environment, causing them to dissolve, other star clusters remain bound for billions of years
- In order to investigate why some star clusters disrupt, and others do not, I will track star clusters through cosmic time in zoom-in Milky Way-like cosmological simulations
- These simulations maintain large scale environmental effects such as bars, spiral arms, gas inflow, while simultaneously resolving small scale star formation and dynamics like those seen in star clusters

The advantages of identifying star clusters in simulations include:

- The ability to witness the birth, evolution, & dispersion of star clusters
- Track individual star clusters over time & in different environments
- Calculate properties of stars within each cluster, such as age & velocity
- Compare to observations to strengthen our understanding of the fundamentals of galaxy formation

Picture of Milky Way-like galaxy: Andromeda. Credit: Robert Gendler

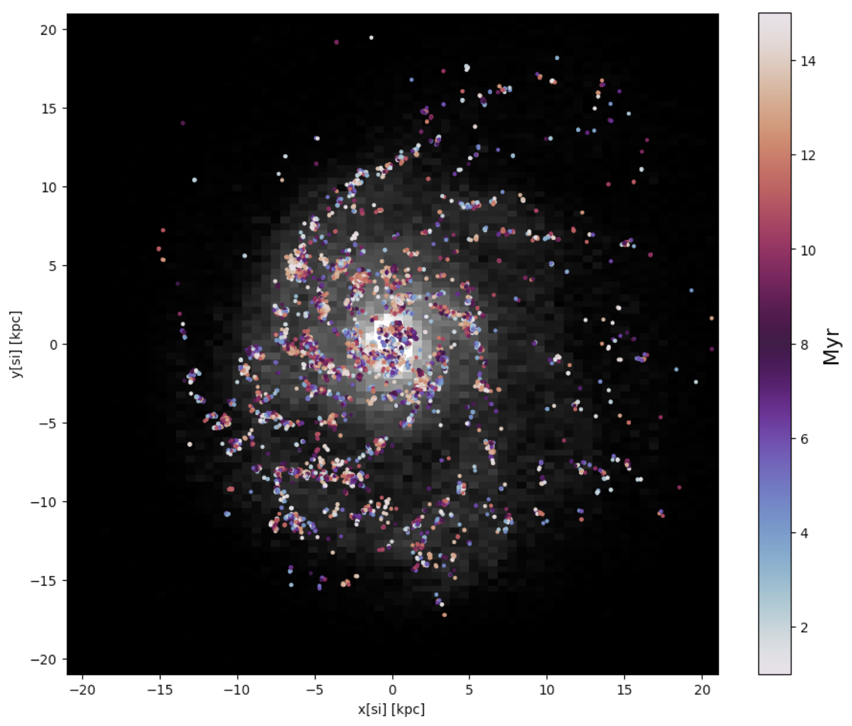


Stars in simulated Milky Way-like galaxy: M12i. Wiggins (in prep)

large-scale gas distribution (left), face-on (middle) and edge-on (right) real-color stellar image of a FIRE cosmological simulation of a Milky Way-mass galaxy. Credit: Andrew Wetzel

FIRE: Feedback In Realistic Environments

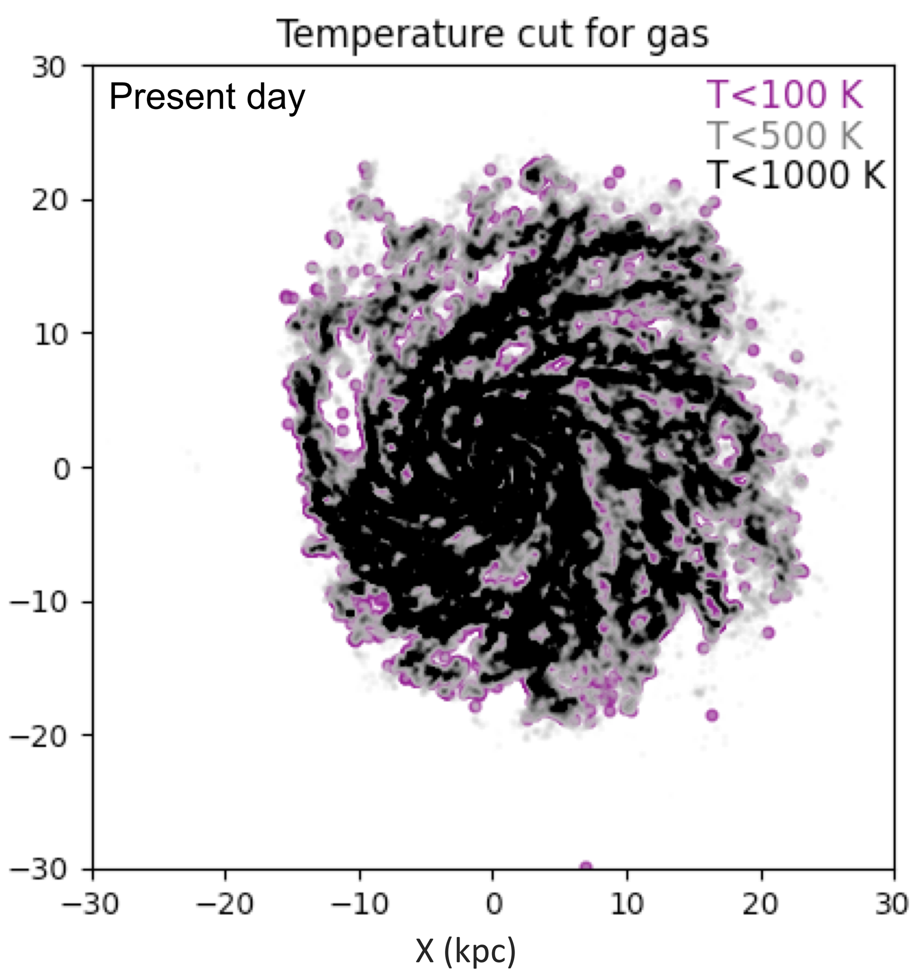
- I work with galaxies generated using the Feedback In Realistic Environment code (FIRE) (Hopkins 2016, 2018)
- FIRE is a Lagrangian code: a code that tracks the location of particles as they flow through a volume over time
- These simulations are seeded from initial conditions soon after the Big Bang, and are evolved using hydrodynamics and the force of gravity
- Each simulation contains dark matter and gas particles Stars form when gas reaches appropriate temperature and density
- In particular, I use the *Latte* suite of FIRE-2 galaxies (Wetzel, 2016), all of which are Milky Way-like zoom-in cosmological galaxy simulations

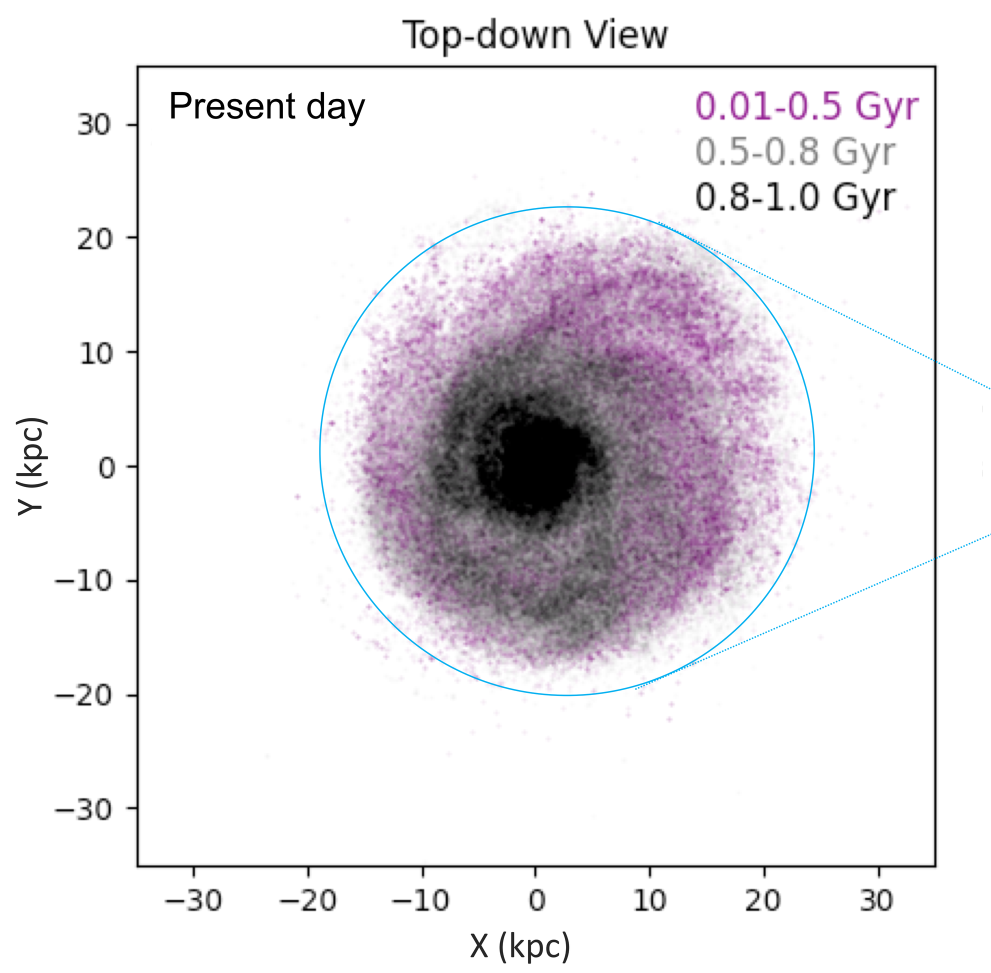


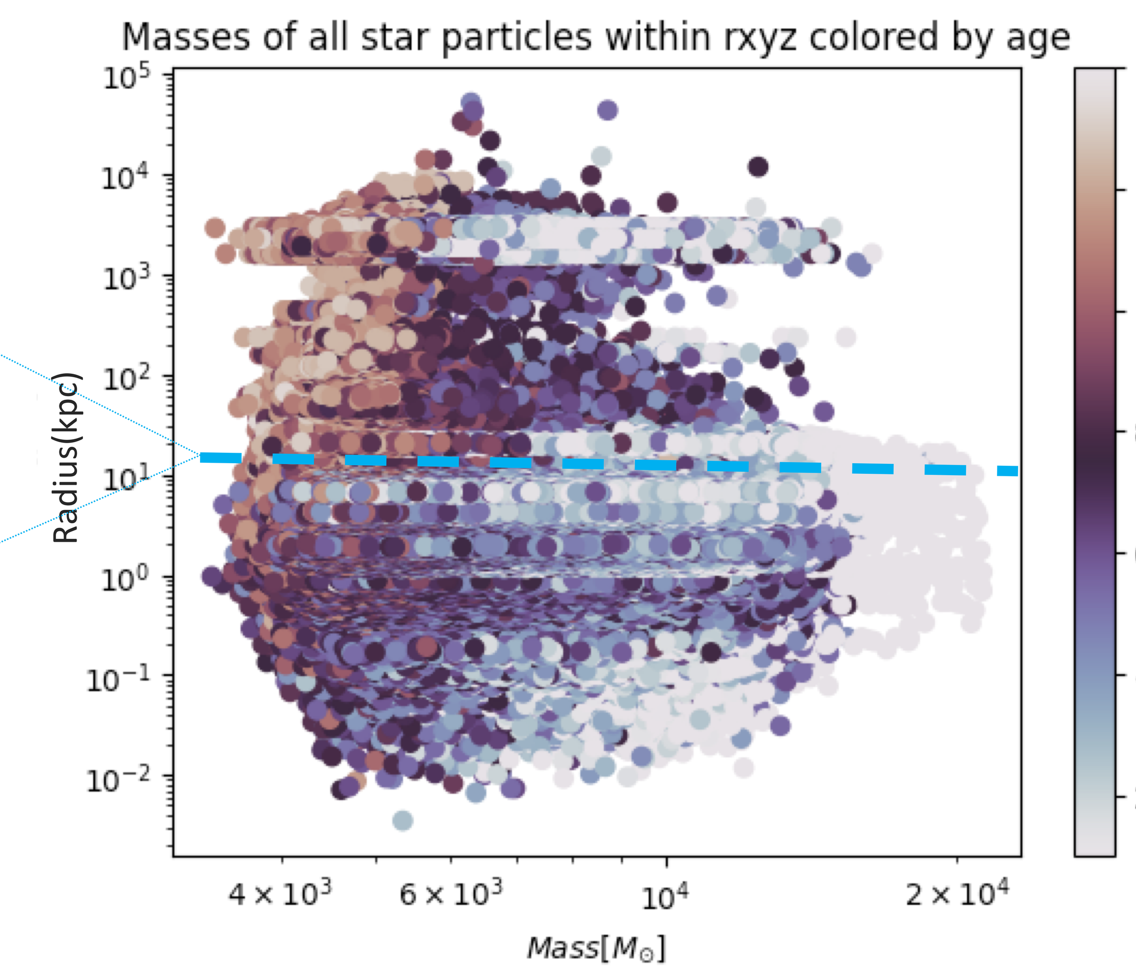
Mock image of a simulated galaxy showing the total star densities in the background, and young stars (1 - 15 Myr) on top

3. Playing with FIRE: initial visualizations of cold gas and young stars in the disk

- In this poster, I am presenting initial visualizations and analysis of one Milky Way-like simulated *Latte* galaxy known as **m12i**. The images below show three different plots that consider stars and gas in m12i, as well as some of their properties (ages, mass, etc.):







3.1 Star Cluster Identification Methodology:

One of the advantages of using our simulations is knowing the exact location and time that stars are formed:

- Because we know when are where stars form, we can connect the stars to the cloud they formed in and to other stars that formed by them
- The way I identify star clusters in our simulations is by using an algorithm that looks for stars that form close together
- This algorithm is known as Friends-Of-Friends (FOF)
- The only requirement for FOF that I have to set in order to identify groups of stars (clusters), is the linking length: the minimum distance between star particles to consider them a part of the same cluster
- For this simulation, I am using the smallest distance that we can resolve as the linking length (4 pc)
- While this linking length is bigger than typical star clusters, this resolution far exceeds the previous resolution that could be obtained by cosmological simulations
- I am currently working on identifying star clusters in this simulation using this linking length. Initial results indicate that roughly a quarter of stars in the simulation form in star clusters, which is on par with expectations in the Milky Way (Dobbs et. al, 2008)

Current questions I would like to answer

Using the star clusters that I have identified, I first want to answer these questions:

1) How much does the larger galactic environment affect how long a star cluster remains bound?

- To answer this, I need to acquire information about the whole galaxy, but the caveat is that I will not be able to resolve very low mass clusters

2) Why do clusters move from their original place of formation and how far they go?

- To answer this question, I need to track the clusters' locations throughout their lifetime, and whether they move in towards the center of the galaxy or out towards the edge

3) Where are the actual clusters in the milky way and how much do their properties match with those we found in our simulation?

- **How common is a cluster like this?**
- **What are the orbits of the clusters found in the simulation?**
- **What impact did the galactic environment have on it?**
- **Did it interact with the spiral structure of the galaxy?**

SciCom

As we know, galaxies are made up of clumps of stars and gas. However, one of the best tools astronomers use to study the evolution of these galaxies is groups of stars known as star clusters. While some of these structures are strongly held together by gravity, many environmental factors can play a role in dissolving them, causing some to fall apart. Zoom-in cosmological simulations, such as FIRE, allow us to investigate the reasons behind these disruption events, which will provide us with a better understanding on how galaxies, like our own, evolve with time.